MAGNETIC DIPOLE MOMENT OF ^{32}Cl

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The study of nuclei around $N = Z$, especially as they become further removed from the line of stability with increasing mass, has long been an area of great theoretical interest. Nuclear magnetic moments, particularly in light nuclei in the *sd* and *fp* shells, provide a sensitive probe into the single-particle nature of nuclei and the structure of nuclear wave functions, since spin *g*-factors are much larger than collective *g*-factors. To date, essentially all mirror magnetic moments in the *sd*-shell have been determined. There still remain several $T = 1$ and $T = 3/2$ multiplet members in the *sd*-shell lacking precise measurement, as well as a few mirror moments in the *fp* shell. These systems are of theoretical interest since isoscalar and isovector contributions to the *M1* operator are readily extracted once dipole moments in an earlier multiplet are known. This, in turn, yields valuable information regarding the role of higher order effects responsible for deviations from Schmidt moments, including configuration mixing and mesonic effects. In the $A = 32$ system only the ^{32}Cl moment remains unknown.

Brown and Wildenthal [1,2] have conducted an extensive theoretical analysis of the single-particle matrix elements of the *M1* and *GT* operators for nuclei in the *sd* shell, working in the context of shell model wave functions which span the $0d_{5/2}$ - $1s_{1/2}$ - $0d_{3/2}$ configurations. They predict magnetic moments for the $A = 32$ system, μ(^{32}Cl, free) = +1.007 μ_N and μ(^{32}Cl, effective) = +1.169 μ_N, which are about half of the Schmidt value of +2.04 μ_N.

We have determined the ground state magnetic dipole moment of ^{32}Cl using the technique of nuclear magnetic resonance on beta-decaying nuclei (β-NMR). The experiments were performed using the A1200 fragment separator at the NSCL. The secondary beam of ^{32}Cl ($T_{1/2}$ = 0.298 s, Q_β = 12.7 MeV, $I^\pi = 1^+$) at 36 MeV/nucleon was obtained after fragmentation of ^{36}Ar at 100 MeV/nucleon in a 642 mg/cm^2 ^{93}Nb target. A polarized ensemble of nuclei was obtained by setting the primary beam at a 2.5^o angle on the target using a combination of two dipole magnets that can swing the beam before the target position [3]. A 425 mg/cm^2 Al wedge-shaped degrader with a slope angle of 3.5 mrad was placed at the second dispersive image of the A1200 to separate the fragment isotopes with given mass-to-charge ratio based on *A* and *Z*. In the best conditions two different isotopes, ^{32}Cl and ^{31}S ($T_{1/2}$ = 2.572 s, Q_β = 5.4 MeV, $I^\pi = 1/2^+$), were detected in the secondary beam using the energy vs. time-of-flight technique. The ratio of the production rates of ^{31}S and ^{32}Cl was about 2:1. The NSCL β-NMR system is described in detail in Ref. [3]. An electromagnet with a pole gap of 10.2 cm was used to provide a holding field in the vertical direction. Two β-telescopes, each consisting of two 4.4 cm × 4.4 cm × 0.3 cm thick ΔE and a 5.1 cm × 5.1 cm × 2.5 cm thick E plastic scintillators were placed between the poles of the magnet at 0^o and 180^o with respect to the holding field. A NaCl single crystal of 2.5 cm diameter × 2 mm thickness was used as a stopper. Two radiofrequency (rf) coils each of 30-turn loops with radius of 1.2 cm and separation of 3 cm were mounted on both sides of the NaCl crystal in a Helmholtz-like geometry. The coil inductance was measured to be 51.4 μH and the coils were arranged such that the resulting rf field was perpendicular to the applied holding magnetic field.

Measurement of the β-asymmetry as a function of the applied rf-field was done in two stages. A continuous beam [3] was used in both experiments. The rf was switched on and off in intervals of 59.5s (rf-on) and 60.5s (rf-off). The data acquisition cycles were taken as 60s "rf-on" and 60s "rf-off". The difference of 0.5s in which the rf is already switched off and the data acquisition still counts for "rf-on" is considered to allow the ^{32}Cl ($T_{1/2}$ = 0.298s) implanted during the rf-on to decay and not to influence the rf-off period. The ratio of the counting rates in the 0° (up) and 180° (down) β telescopes both for rf-on and rf-off conditions was considered.

$$R = (up/down)_{rf\text{-}on}/(up/down)_{rf\text{-}off} \tag{1}$$

Triple coincidences between each element of the β-telescopes were used to discriminate β- and γ-rays. To avoid the influence of the ^{31}S contaminant on the measured β asymmetry, an off-line energy discrimination was performed on the spectra collected in the E detectors. Since $Q_\beta(^{31}S) << Q_\beta(^{32}Cl)$ only the higher energy part of the β-spectrum was taken into account. Using such an energy threshold, one also discriminates a mixed Fermi/Gamow-Teller transition ^{32}Cl, $1^+ \rightarrow {}^{32}S$, 1^+ which accounts for 20.5% of the total β intensity [4] and has unknown F/GT mixing ratio. By eliminating this F/GT transition, the asymmetry factor for the ^{32}Cl β decay is calculated to be $A_1 = 0.31$. During the first measurements the holding magnetic field was set to 1002.2(2) G. A scan in the frequency range 675 to 975 kHz with a frequency modulation (FM) of ±25 kHz resulted in an asymmetry change of more than 5 standard deviations (Figure 1a, open circles). The two filled-circle points plotted in Figure 1a were taken during the second experiment, which confirmed the initial results.

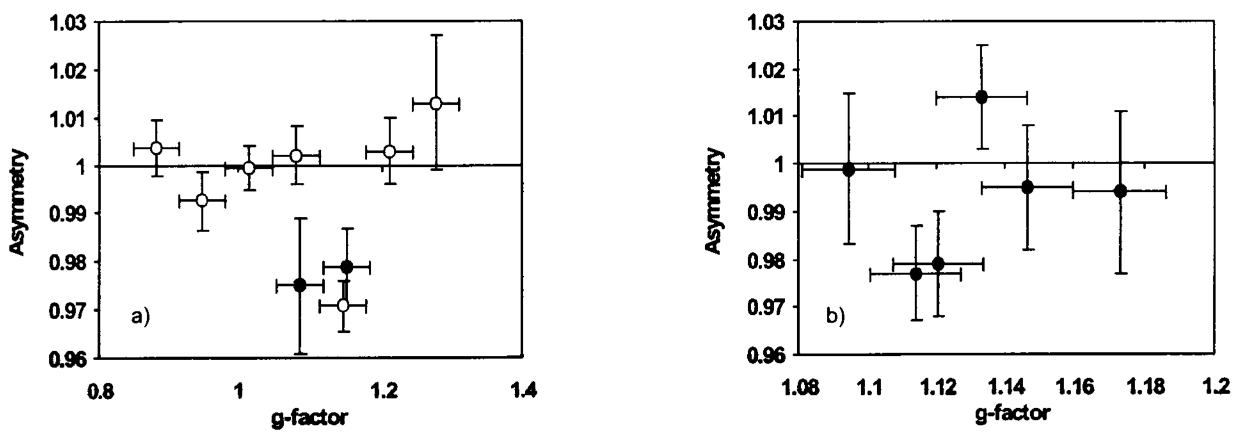

Figure 1: β-asymmetry v. *g*-factor for ^{32}Cl with a) FM = ±25 kHz and b) FM = ± 10 kHz. The open circle points were collected with B_{app} = 1002.2(2) G. For the filled circle points, Bapp= 1001(1) G.

To achieve better accuracy of the deduced magnetic moment of ^{32}Cl a smaller frequency modulation was also used during the second measurement. The holding magnetic field was set to 1001(1) G and a frequency window from 835 to 895 kHz was scanned at a frequency modulation of ±10 kHz (Figure 1b). The value $\mu(^{32}Cl) = 1.114 \pm 0.006$ (statistical) ±0.001(systematic) μ_N was obtained. The statistical error includes only the uncertainty from the frequency window of the FM. The systematic error is due primarily to the uncertainty of the holding field. The deduced moment of ^{32}Cl agrees well with the shell model predictions of Brown and Wildenthal.

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